Formation Algorithms and Simulation Testbed

Matt Wette, Dan Scharf, Eli McMahon, Ed Benowitz
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Dr.
Pasadena, CA 91109

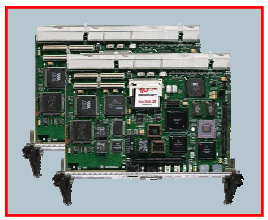
2003 TPF Expo
Oct 14-16, 2003
Pasadena, CA

[version 1.09]

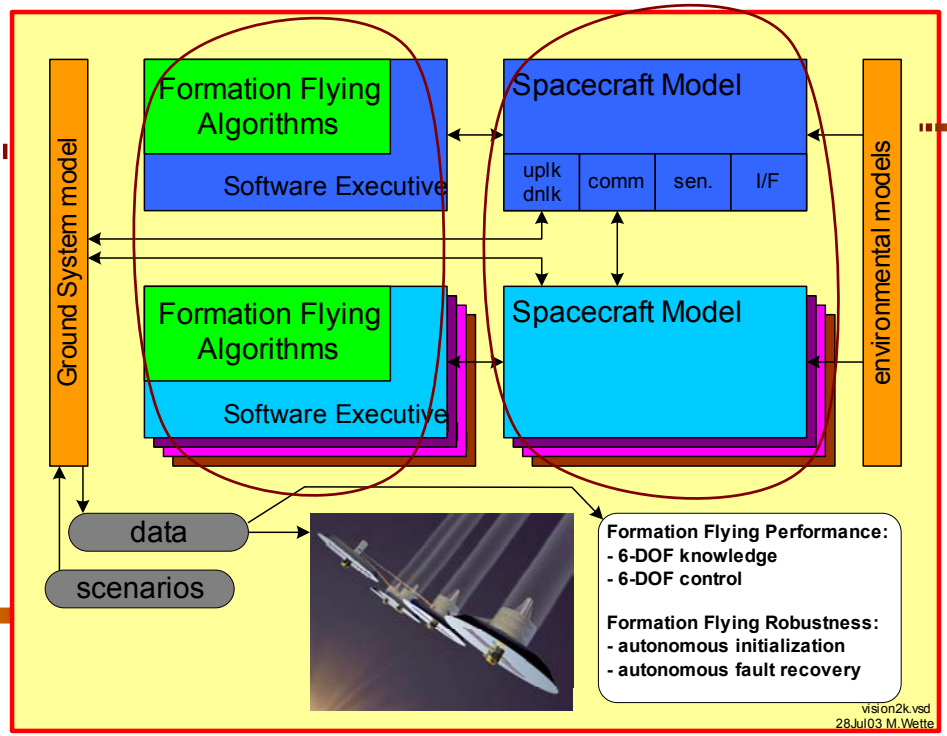
Formation Algorithms and Simulation Testbed

A Distributed Real-Time Simulation Testbed for Formation Flying

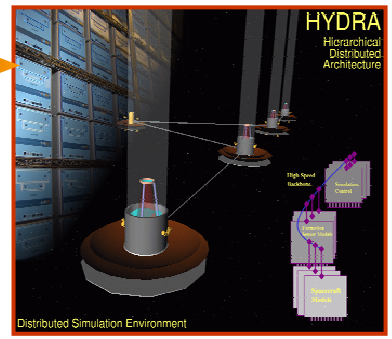
Flight algorithms executing on flight-like processors

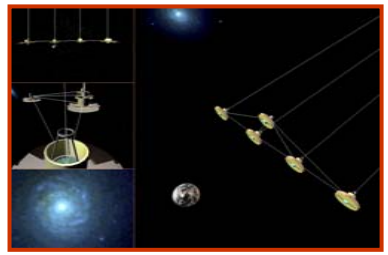


Flight scenario studies



Highly scalable simulation environment





FAST is a testbed that demonstrates the end-to-end operation of multiple spacecraft formation flying in a distributed real-time simulation environment.

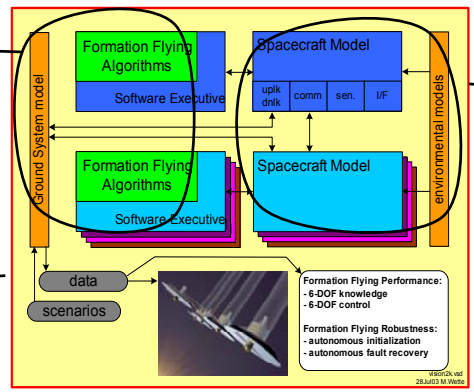
Motivation for FAST

- Some TPF concerns regarding Formation Flying (FF):
  - System Functionality
    - Formation deployment and initialization
    - Collision avoidance (in the presence of faults)
    - Fuel balancing
    - Complexity of end-to-end operation
  - Coarse Formation Control
    - Collision avoidance
    - Sun avoidance
    - Target acquisition
  - Fine Formation Control
    - Station-keeping
    - On-the-fly observation
    - Instrument interactions
    - Synchronized thruster firing

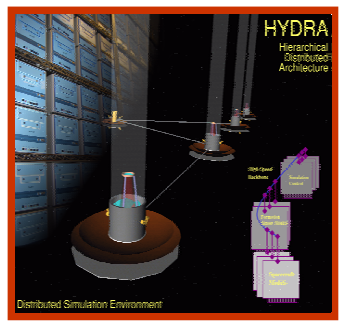
The FAST Objective and Approach

- Objective
  - Demonstrate end-to-end operation of multiple spacecraft formation flying in a distributed real-time simulation environment
- Approach:
  - Leverage existing formation flying algorithms for TPF:
    - NASA Code R Distributed Spacecraft Technology
    - StarLight Project Phase A development
  - Leverage existing distributed simulation environment:
    - NASA Code R Distributed Spacecraft Technology
  - Extend and integrate for TPF:
    - Five spacecraft TPF formation control
    - Workstation simulation environment
    - Distributed real-time simulation environment
  - Simulate TPF flight scenarios

flight algorithms on flight-like processors



highly scalable simulation environment



flight scenario studies

Terrestrial Planet Finder Mission

TPF

A NASA Origins Mission

Features of the FAST

Terrestrial Planet Finder Mission

TPF

A NASA Origins Mission

- Advanced algorithms for formation flying
  - Formation guidance (with collision avoidance)
  - Formation estimation
  - Formation control
- Inter-spacecraft time synchronization
- Distributed real-time execution on multiple flight-like processors
- Fault tolerance
  - Spacecraft computer reset
  - Thruster misfire
  - Sensor failure
  - Inter-spacecraft communication dropouts

formation control algorithms and software

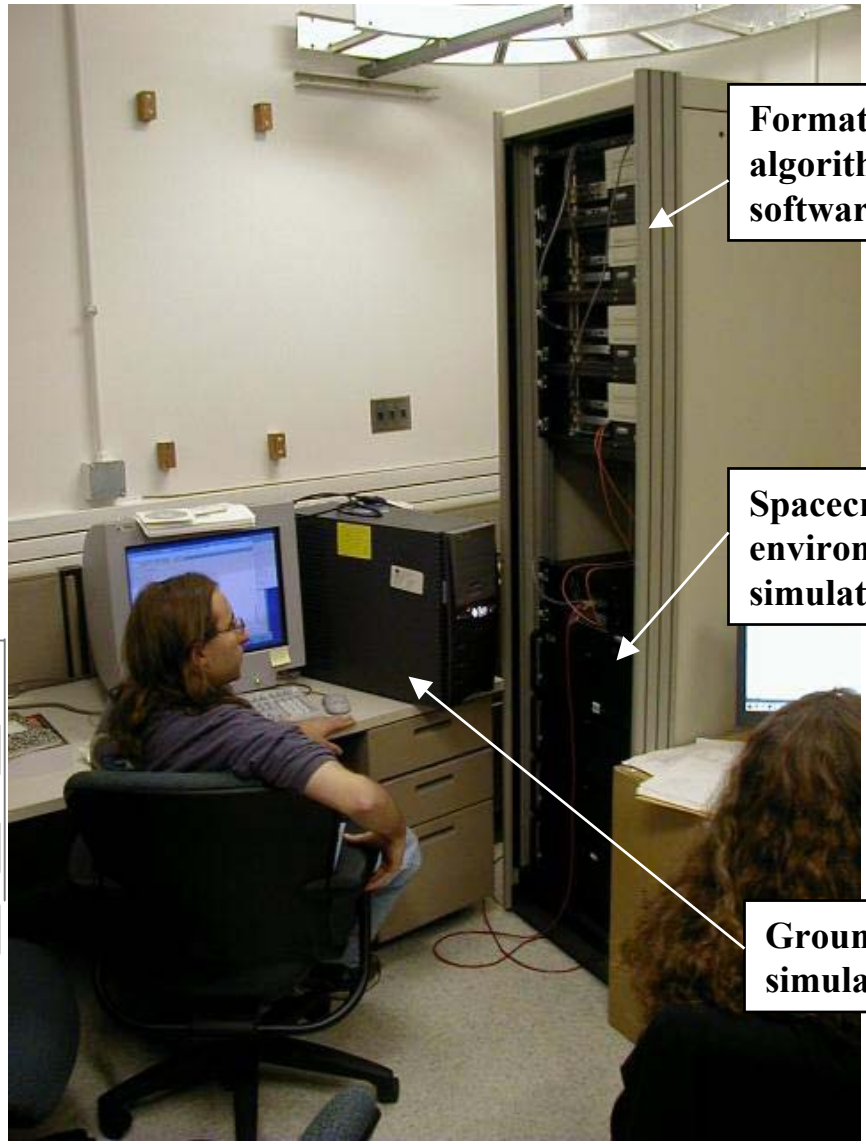
- Relative sensor suite models [acquisition, medium, fine sensors]
- Distributed real-time simulation on Beowulf cluster
- Inter-spacecraft communication model [latency, throughput, connectivity]
- Functional interferometer model [demonstrates capability for formation flying to interferometer hand-off]

spacecraft and environment simulation

FAST Plan

- Demonstration of distributed real-time (DRT) simulation environment
  - 2003: Two-spacecraft design running on distributed real-time system
- TPF formation flying nominal operations
  - 2004: TPF 5-spacecraft nominal operations on desktop workstation
  - 2005: TPF 5-spacecraft nominal operations in distributed real-time
- TPF formation flying off-nominal operations
  - 2005: TPF 5-spacecraft off-nominal operations on workstation
  - 2006: TPF 5-spacecraft off-nominal operations on DRT system
- TPF formation flying operation with interferometer
  - 2007: TPF operation with hand-off to interferometer on DRT system

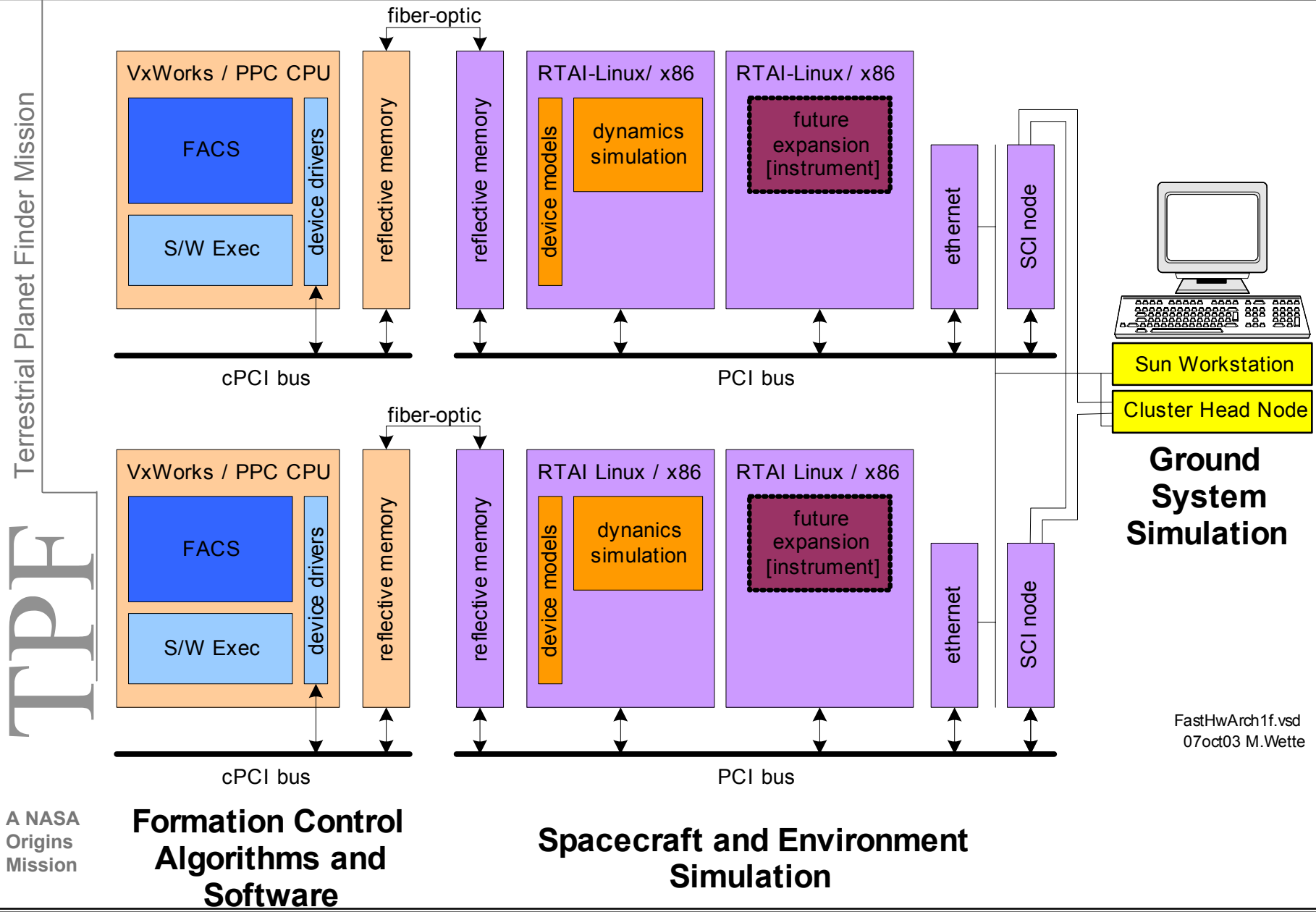
FAST - Current Status



- Formation Attitude Control Algorithms (FACS) run with Software Executive on flight-like PowerPC CPUs running VxWorks.
- Environment simulation runs on a "cluster computer" with Intel Pentium processors running a real-time Linux.
- Console for commanding, telemetry collection and data analysis on desktop workstation.

See Demo

FAST Hardware Block Diagram



Summary

- The FAST will address top concerns of formation flying for TPF.
- The FAST is enhancing formation flying technology readiness to prove viability by 2006.
- The FAST is approaching this by proving performance and robustness of algorithms and software on flight like processors executing in a flight-like environment.

Terrestrial Planet Finder Mission

TPF

A NASA Origins Mission

The work described here was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.